APPENDIX B
DESIGN CALCULATIONS

1.0 INTRODUCTION
This appendix presents a description of the general types of calculations that may be required for LFG applications. The calculations described refer primarily to the off-gas collection systems. Additional calculations may be necessary for specific type of LFG collection and treatment technology or for specific types of equipment selected. Several of these calculations are dependent on, or should be used in conjunction with, other calculations that should be performed or used in the development of the design for the entire treatment process or treatment facility. Design examples illustrating the use of several of these calculations are presented in Appendix E.

2.0 PURPOSE
The primary purpose of the design calculations is to provide design criteria for sizing equipment, editing guide specifications and developing construction drawings. Based on the preliminary selection of equipment, additional calculations can also be performed to determine parameters such as utility requirements and supporting mechanical and electrical distribution systems.

3.0 DESIGN CALCULATIONS
3.1 ASSUMPTION OR DEFAULT VALUES
Gas Production

Methane (CH_4) generation rate: Estimated by the Scholl Canyon model.

LFG generation rate: Twice the methane generation rate.

Gas Characteristics

CH_4 concentration of the LFG: 50 percent.

Extraction Well Design

Default vacuum pressure at each extraction well:

1.01×10^5 N/m^2 (.9928 atm)

The depth of the extraction wells is 75 percent that of the landfill depth.

Blower System

Capacity of blower, Q_c = $m^3.min^{-1}$ ($35.30 ft^3.min^{-1}$)

Maximum gas velocity, V = 914.4 m/mm (2000 ft/mm) through the piping.

Condensate System

Condensate is calculated based on LFG enters collection system at 100 percent saturation. Cools to 12.7^0C (55^0F)

3.2 CALCULATION FORMULAE

3.2.1 Estimation of LFG Generation Rate

$$Q = 2 * k * L * R^{-k(t-tag)} \tag{1}$$

where,

Q = LFG generation rate at time t, m^3/yr (ft^3/yr)
k = refuse decay rate, 1/yr
L = potential gas generation capacity, m^3/ton (ft^3/ton)
R = refuse acceptance rate, tons/yr
t = time since refuse placement, years
lag = time to reach anaerobic conditions, years

3.2.2 Radius of Influence, ROI

$$\boldsymbol{ROI = (Q_{wDESIGN} Capacity / \pi L \rho_{refuse} Q_{gen}{}^{1/2}} \tag{2}$$

where,

ROI = radius of influence, m
$Q_{wDesign}$ = design LFG generation rate, m^3/yr
Capacity = design capacity of the landfill, kg
B = 3.14
D_{refuse} = refuse density, kg/m^3
Q_{gen} = peak LFG generation rate, m^3/yr
L = landfill depth, m

3.2.3 Landfill Pressure, P_L

$$P_L = [(\frac{P_v\,(ROI^2 \ln(ROI/r)\ \mu_{lfg}\ \rho_{refuse}\ Q_{gen}}{Design\ Capacity\ K_{refuse}\ (WD/L)} * 3.15 \times 10^{-7}) + P_v^2]^{1/2} \quad (3)$$

where,

P_L	=	landfill pressure, KN/cm^2
ROI	=	radius of influence, m
Pv	=	vacuum pressure at the well head, KN/m^2
r	=	radius of outer well (or gravel casing), m
D_{refuse}	=	refuse density, 650 kg/m^3
k_{refuse}	=	intrinsic refuse permeability, m^2
μ_{lfg}	=	LFG viscosity, Newton-sec/m2
Design Capacity	=	design capacity of the landfill, kg
WD	=	well depth (i.e., 0.75L), m
L	=	landfill depth, m
Q_{gen}	=	peak LFG generation rate, m^3,yr

3.2.4 Optimal Number of Extraction Wells, $Wells_{TOT}$

$$Wells_{TOT} = (\text{Landfill surface area})/B.(ROI)^2 \quad (4)$$

where,

$wells_{TOT}$	=	total number of wells required
B	=	3.14
ROI	=	radius of influence, m

3.2.5 Header Pipe sizing

$$\text{Diameter} = \frac{\text{Mass flow rate, kg/hr}}{\text{LFG denity, kg/m}^3}$$

or

$$\text{Diameter}^{(17)} = 1.414 * (W^{0.408}/D^{0.343}) \quad (5)$$

where,

W	=	LFG mass flow rate, (1,000 lb/hr)
D	=	LFG density (lb/ft^3)
1.414	=	conversion factor

or

$$\text{Diameter} = W / 2000\ ft.sec^{-1} \quad (6)$$

where,

W = LFG mass flow rate, (1,000 lb/hr)
2,000 = minimum LFG velocity in the piping, ft/sec

3.2.6 Pipe head-loss

$$h_L = \frac{fL}{d} \times \frac{V^2}{2g} \qquad (7)$$

where,

hL = Head loss, m (ft)
L = Length of segment, m (ft)
f = Friction factor for the pipe
d = Inside diameter of the pipe
V = Velocity of the flow, m/sec (ft/sec)
g = Acceleration due to gravity, 9,81 m/sec (32.2 ft/sec).

The friction factor f is based on the Reynolds Number (R_e) and the roughness of the header pipe. Moody Diagramx is used to estimate friction factor based on R_e.

3.2.7 Motor horsepower requirement

$$W_{SM} = \frac{Q_{TOT}\,(\Delta P_{TOT})}{3.1536 \times 10^7\,(.65)} \qquad (8)$$

where,

W_{SM} = watt
Q_{TOT} = total gas producton rate, m^3/min
P_{TOT} = total system pressure drop, N/m^2
.65 = motor efficiency

3.2.8 Number of Blowers required

$$No.\ Blowers = Q_{TOT}/(283.2\ m^3/min) \qquad (9)$$

where,

Q_{TOT} = total gas production rate, m^3/min
283.2 m^3/min = maximum blower flow rate

3.2.9 Condensate Flowrate, Q_{cond}

$$Q_{cond} = \frac{.0203\ Q_{TOT}}{760 - 1.87 \Delta P_{TOT}} \tag{10}$$

Where,

Q_{cond} = flow rate of condensate, m^3/min
Q_{TOT} = total gas production rayte, m^3/min
$)P_{TOT}$ = total system pressure drop, N/m^2

Alternatively, condensate can be calculated by assuming:

100% relative humidity
Density of condensate = Density of water
Piping temperature 55°F

Calculations are as follows:

Calculations are as follows:

1. Water concentrations (# water/cu.ft wet air)= Humidity(# water/# dry air) * (Specific volume (cu.ft/# dry air)

2. Volume of water extracted (gal/day) = water concentration (#/cu.ft)*flow rate (cfm) * 1440 min/day)* 0.12 (gal/#)

3. Volume of water condensed (gal/day) = Volume of water extracted at °F - volume of water extracted at 55°F.

4.0 UTILITY CALCULATIONS

4.1 POWER REQUIREMENTS

Several types of calculations for power requirements can be used in the design of an LFG application including a normal load and lead protection analysis, a ground fault current analysis, and lighting analysis. These types of calculations are usually performed as part of the electrical calculations provided for the entire treatment facility.

4.2 Water Requirements

Systems that typically require potable water include:

- ! sanitary,
- ! emergency shower and eye wash, and
- ! fire water.

Based on the specific requirements for each of these applications, calculations will be performed for the quantity of potable water required and associated distribution systems.

4.3 Air Requirements

The calculations that are performed for the air system include those for sizing the air compressors and those for sizing air distributions systems.

Additional calculations performed for the distribution systems include those required for sizing air receivers, air dryers, and the distribution piping system. These calculations are primarily based on the specific air requirements for each individual demand.

5.0 ADDITIONAL REOUIREMENTS

In addition to the process, mechanical, and electrical calculations, additional design requirements and calculations that may be required for LFG applications include those related to architectural requirements such as the determination of aisle space, equipment clearances, and storage space; structural requirements for the purification units, supporting accessories, and chemical storage; and operation and maintenance provisions. However, these types of calculations are application-specific; therefore, no specific calculations are provided in this Appendix.